Offset Frontal Collisions and the Effect on Opposite Side Occupants

Using Crash Data to Identify People with Critical Injuries that are Difficult to Detect

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The William Lehman Injury Research Center

University of MIAMI

Outline

- Validation of URGENCY Algorithm to Detect Severe Injuries
- Corrections in Algorithms due to Offset Crashes
- Examples of injuries in Offset Crashes

Definition of Automatic Crash Notification (1st Generation)

- Identifies that a Crash Has Occurred
- Identifies the Crash Location
- Automatically Transmits the Information to a Third Party Who Dispatches Assistance

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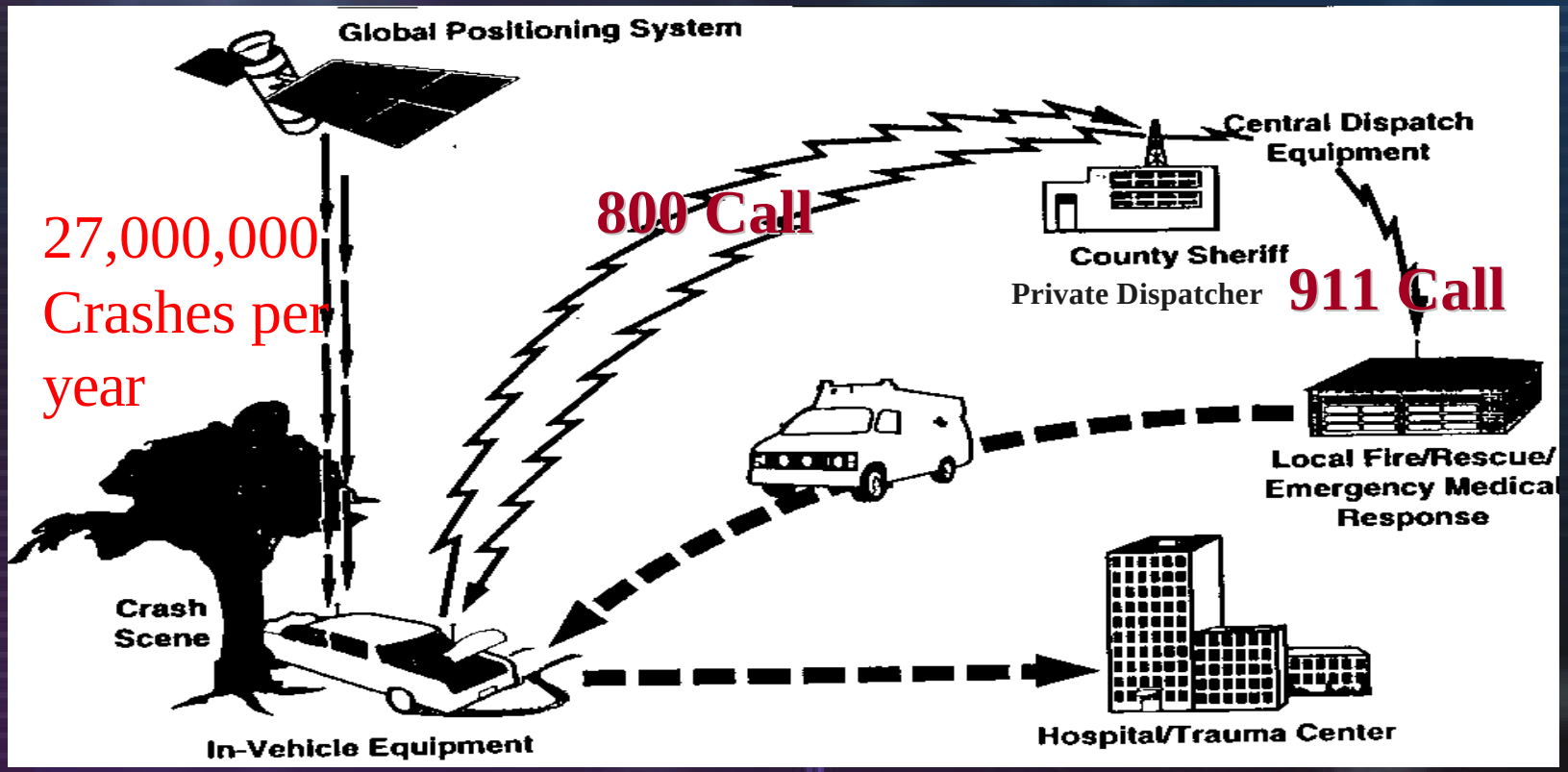
Automatic Crash Notification



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Crash Signal Information

NHTSA/Calspan ACN System

- Delta-V
- Principal Direction of Force (PDOF)
- Rollover Indicator/Counter
- Travel Speed
- Vehicle Data (VIN Related)
- *2-Way Voice Communications*

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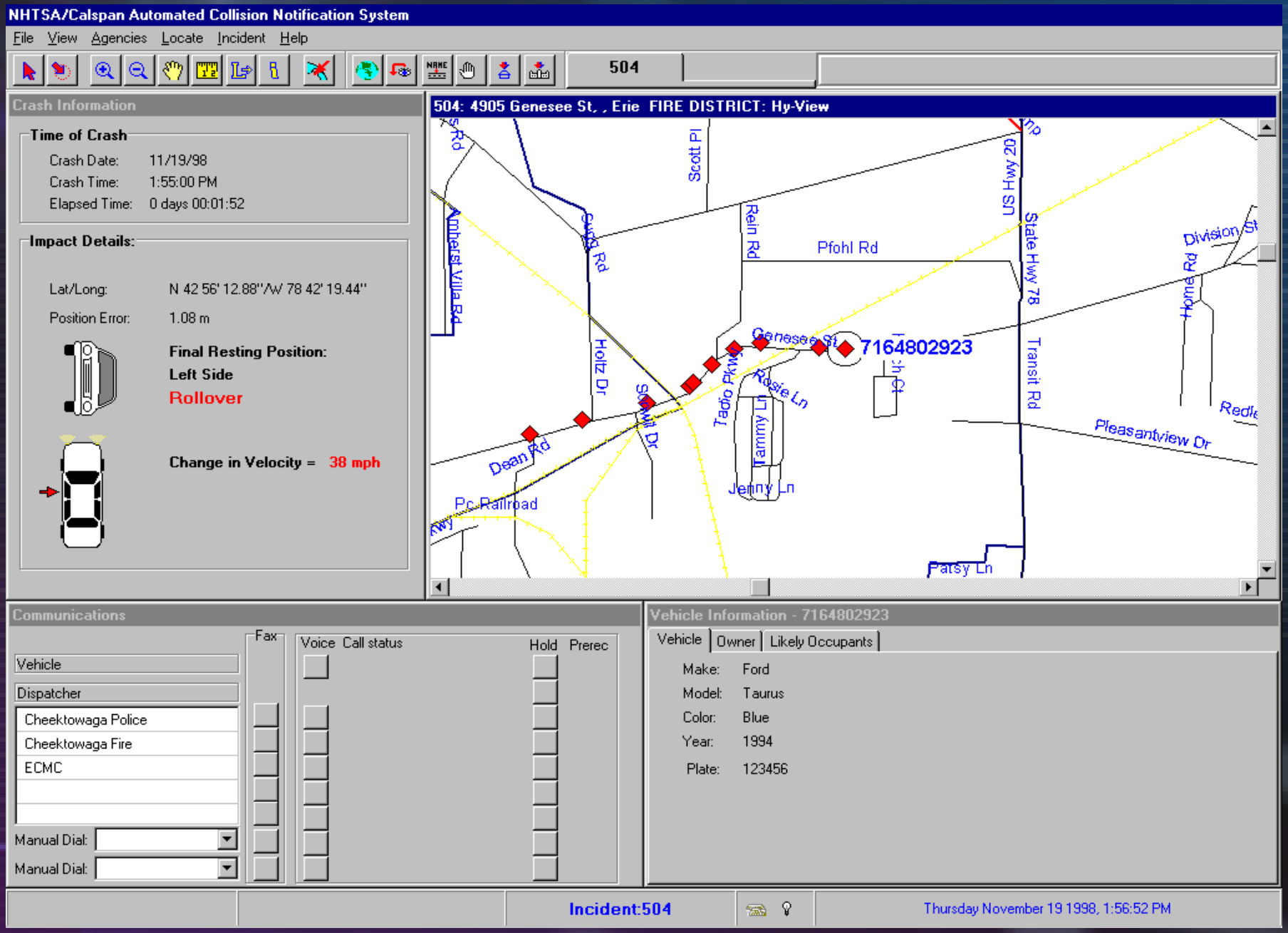
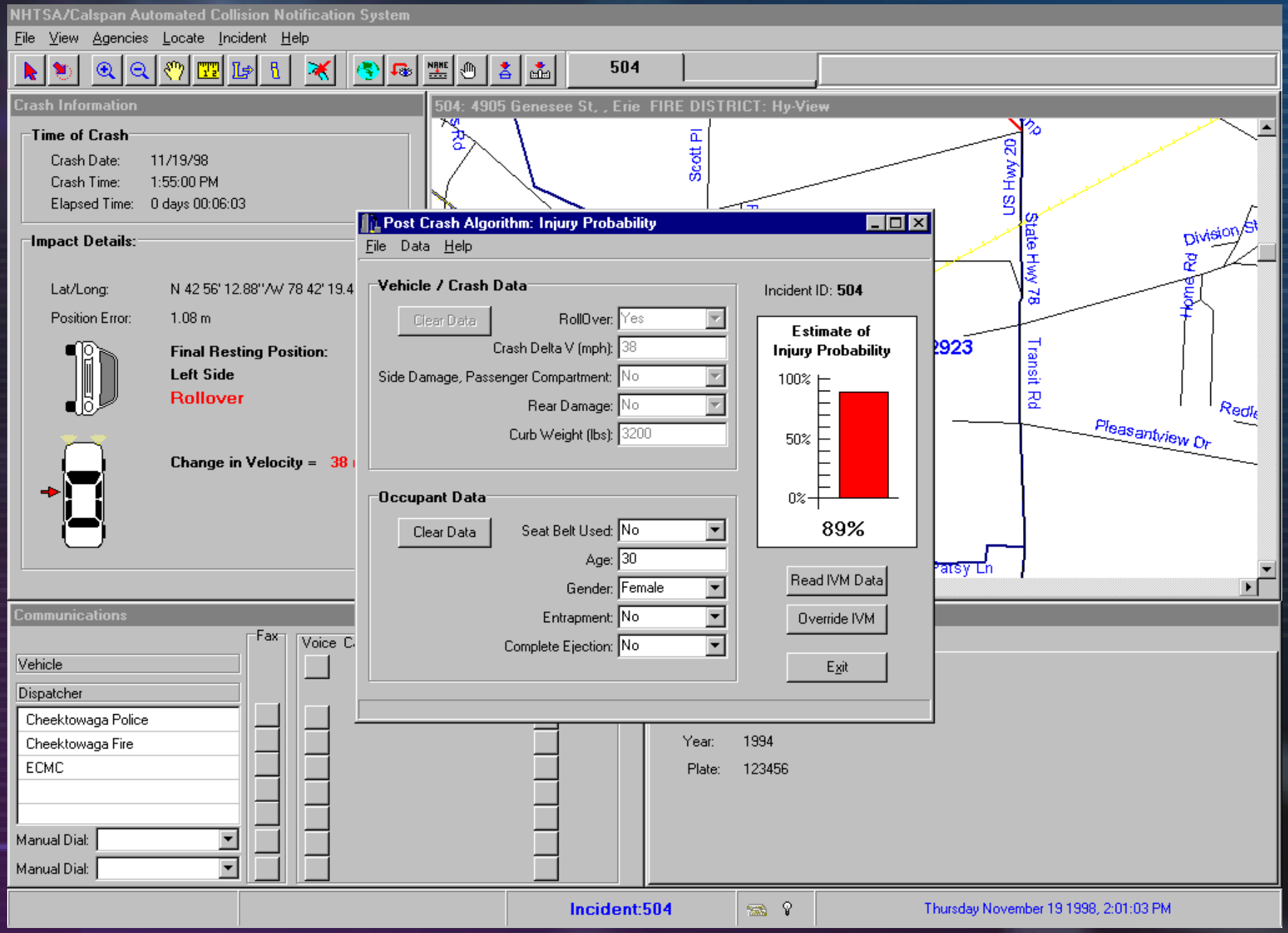
Crash Vehicle Location



URGENCY Estimate of Serious Injury Probability



URGENCY Predictors of Injury

- Delta V & PDOF
- Rollover
- Belt Use
- Single Vs. Multi-vehicle Crash
- Extent of Damage
- Ejection & Entrapment
- Age & Gender
- Vehicle Weight

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Injury Predictor Algorithm

Probability of Injury (P) Using Logistic Regression Analysis with Weighting Factors

$$P = 1/[1+\exp(-w)]$$

$$w = Ao + A1*Pred\ 1 + A2*Pred\ 2 + ...$$

Ao = Intercept

An= Coefficient

Pred n= Value of Predictor

Principle of Maximum Likelihood

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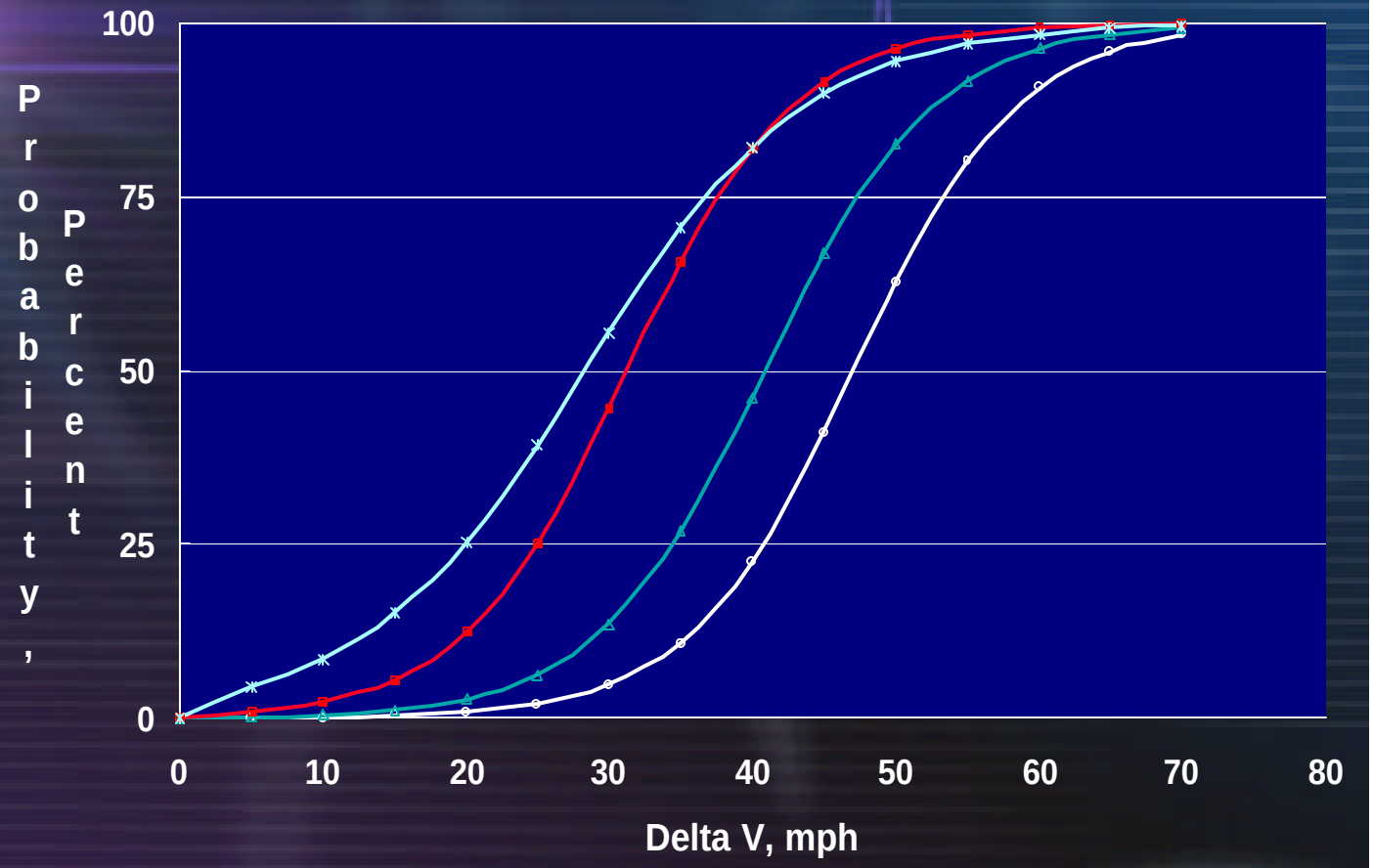
Probability of Shown Outcome Using Car Crash Severity



Probability of Casualty Levels Using DeltaV only

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The NASS/CDS 1988-1995

A_n for MAIS 3+ Injury Risk Binary Factors

Predictor	A
SINGLE	0.322
ROLL	1.157
GADSP	0.219
GADB	-1.793
OCCRE	-0.65
FEMALE	0.464
ENT	2.378
EJC	1.859

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Source: Malliaris. SAE 970393, 1997

A_n for MAIS 3+ Injury Risk Continuous Variables

Predictor	A
TOTALDV	0.164
AGE	0.042
MAX CRUSH	0.037
CURBWT	-0.027

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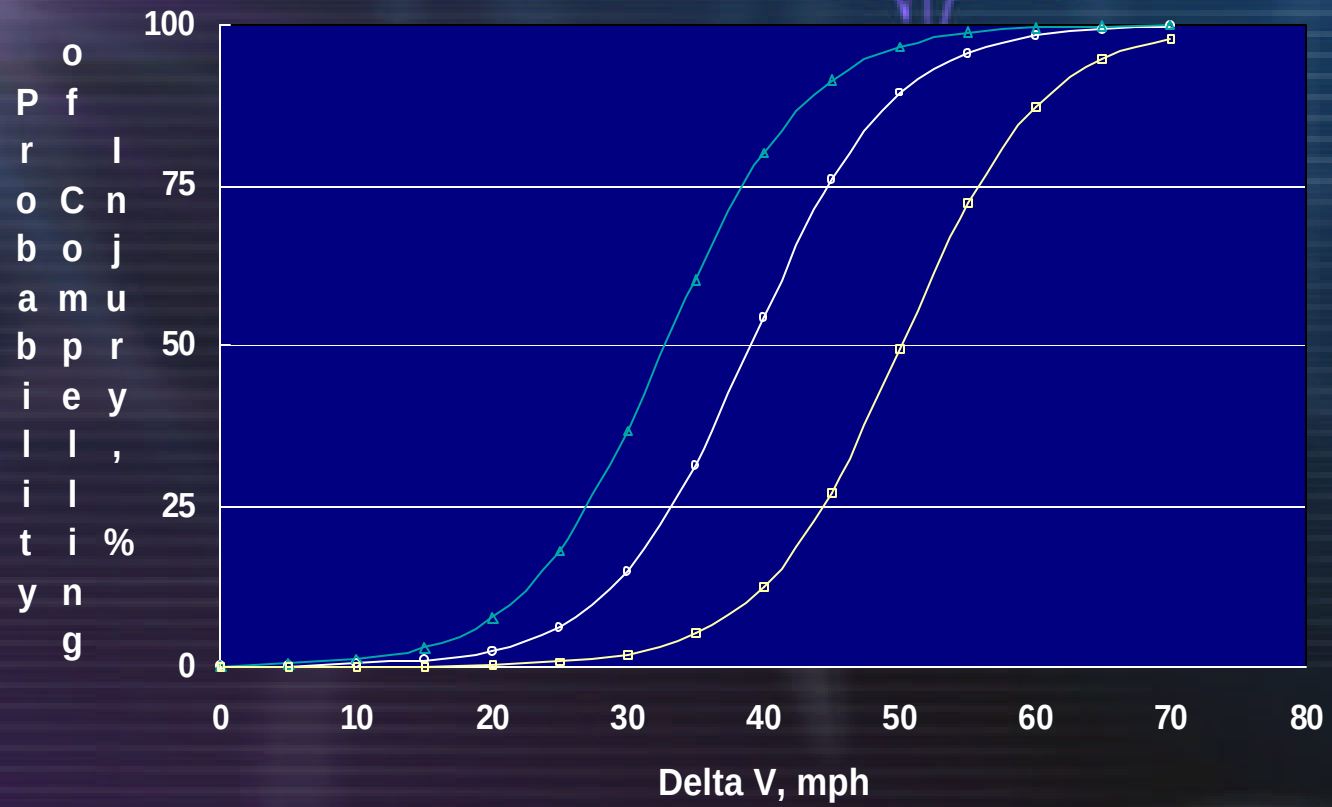
Source: Malliaris. SAE 970393, 1997

Sensitivity of Severe Injury to the Direction of Force, as a Function of Car Crash Severity



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The NASS/CDS 1988-1995

Application to Field Cases

- Frontal Crash
- Restrained Occupant
- 30 YO Male Driver
- 30 mph vehicle-to-vehicle crash
- 3200 Lb Car
- What is the probability of an AIS 3 Injury?

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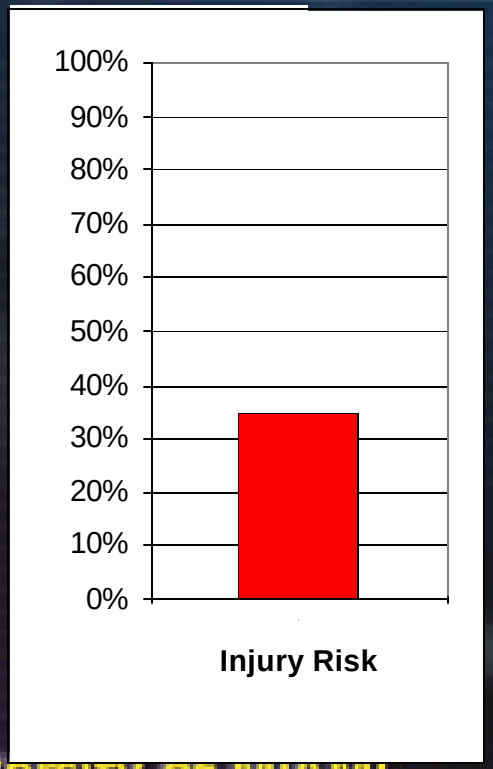
Baseline MAIS 3+ Injury Risk 3200 lb Car

Vehicular Crash Data Frontal Crashes	Value	Data Check
DELTAV, in MPH?	30	
ROLL? (NO=0, YES=1)	0	TRUE
Single Vehicle? (NO=0. YES=1)	0	TRUE
Max Crush (in.)	22	
Car Curb Weight, in lbs.? (Default 3200 lbs.)	3200	
Air Bag + 3Pt Belt? (NO=0, YES=1)	0	TRUE
3 Pt Belt Only? (NO=0, YES=1)	1	TRUE
Car Occupant's Age, in years? (Default 30 yr.	30	
Occupant's Gender? (FEMALE=1, MALE=0)	0	TRUE
Entrapment? (NO=0, YES=1)	0	TRUE
Complete Ejection? (NO=0, YES=1)	0	TRUE
Partial Ejection? (NO=0, YES=1)	0	TRUE
Probability of Severe Injury	**35%**	

Probability of MAIS 3+ Injury



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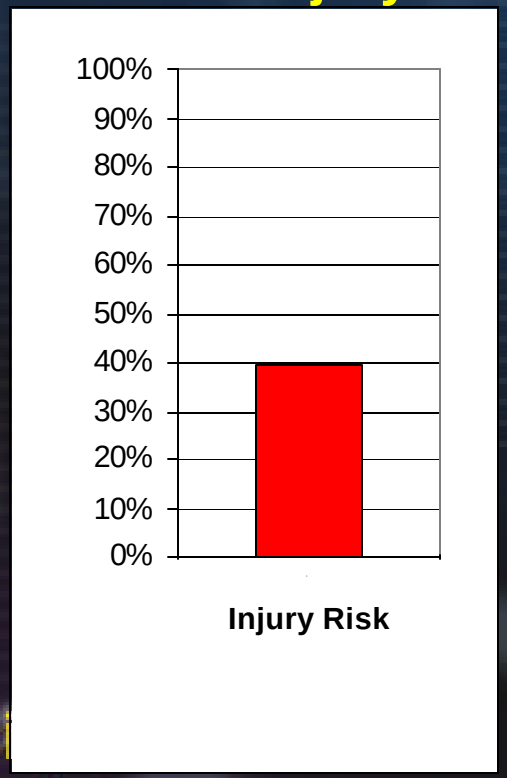
MAIS 3+ Injury Risk
2400 lb Car

Vehicular Crash Data Frontal Crashes	Value	Data Check
DELTAV, in MPH?	30	
ROLL? (NO=0, YES=1)	0	TRUE
Single Vehicle? (NO=0. YES=1)	0	TRUE
Max Crush (in.)	22	
Car Curb Weight, in lbs.? (Default 3200 lbs.)	2400	
Air Bag + 3Pt Belt? (NO=0, YES=1)	0	TRUE
3 Pt Belt Only? (NO=0, YES=1)	1	TRUE
Car Occupant's Age, in years? (Default 30 yr.	30	
Occupant's Gender? (FEMALE=1, MALE=0)	0	TRUE
Entrapment? (NO=0, YES=1)	0	TRUE
Complete Ejection? (NO=0, YES=1)	0	TRUE
Partial Ejection? (NO=0, YES=1)	0	TRUE
Probability of Severe Injury	**40%**	

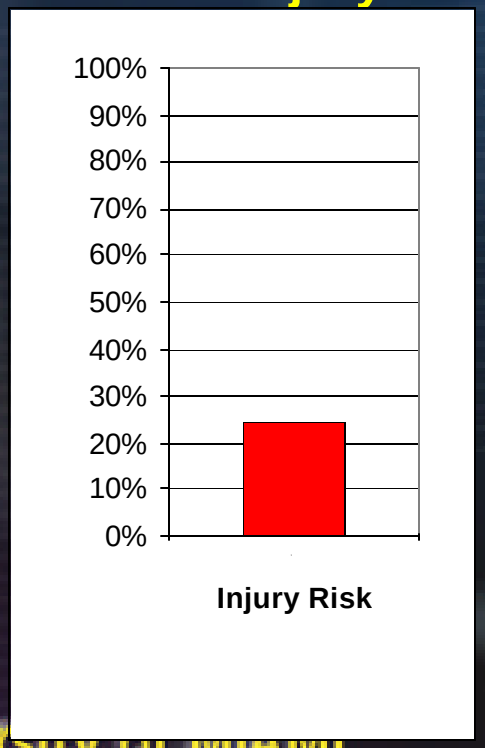
Probability of MAIS 3+ Injury



MAIS 3+ Injury Risk
2400 lb Car (Belt+ Bag)

Vehicular Crash Data Frontal Crashes	Value	Data Check
DELTAV, in MPH?	30	
ROLL? (NO=0, YES=1)	0	TRUE
Single Vehicle? (NO=0. YES=1)	0	TRUE
Max Crush (in.)	22	
Car Curb Weight, in lbs.? (Default 3200 lbs.)	2400	
Air Bag + 3Pt Belt? (NO=0, YES=1)	1	TRUE
3 Pt Belt Only? (NO=0, YES=1)	0	TRUE
Car Occupant's Age, in years? (Default 30 yr.	30	
Occupant's Gender? (FEMALE=1, MALE=0)	0	TRUE
Entrapment? (NO=0, YES=1)	0	TRUE
Complete Ejection? (NO=0, YES=1)	0	TRUE
Partial Ejection? (NO=0, YES=1)	0	TRUE
Probability of Severe Injury	**24%**	

Probability of MAIS 3+ Injury



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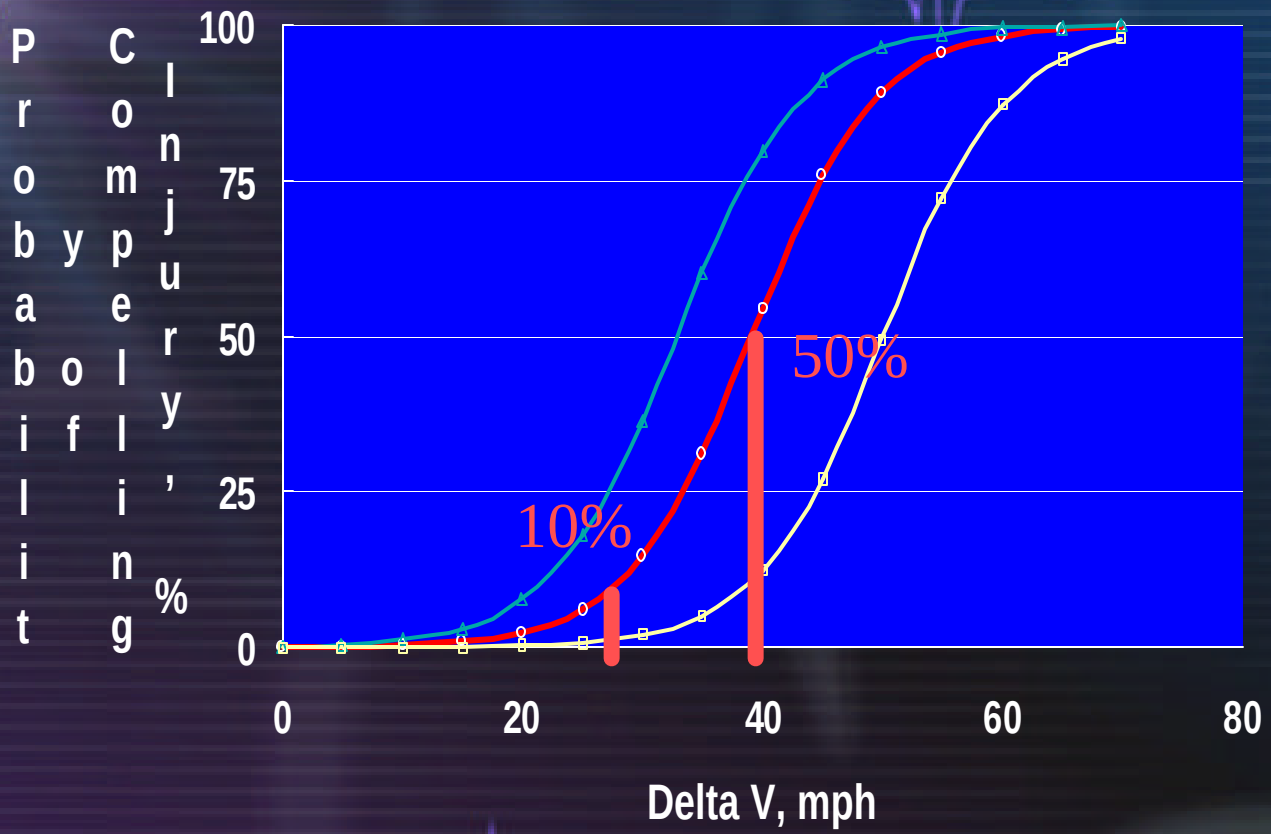
Sensitivity of Severe Injury to the Direction of Force, as a Function of Car Crash Severity



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The NASS/CDS 1988-1995

Validation of URGENCY Algorithm

Apply to WLIRC Cases with the Following Criteria:

- Frontal Crashes
- Belt + Air Bag

Cases that met Criteria

- 7 DOS
- 20 Met Physiological Triage (16 with MAIS 3+)(4 No)
- 30 Hi Suspicion of Injury (18 with MAIS 3+)(12 No)

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URGENCY Validation - Baseline Prediction

	Low Risk	Med Risk	Hi Risk
Baseline	**0-10**	**11-49**	**50+**
DOS	0/	0/	7/
TRAUMA	8/	4/	8/
HI SUS	8/	11/	11/

URGENCY Validation - Baseline Accuracy

	Low Risk	Med Risk	Hi Risk
Baseline	**0-10**	**11-49**	**50+**
DOS	0/0	0/0	7/7
TRAUMA	8/4	4/4	8/8
HI SUS	8/2	11/6	11/10

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URGENCY Validation - Pole +

	Low Risk	Med Risk	Hi Risk
Baseline	**0-10**	**11-49**	**50+**
DOS	0/0	0/0	7/7
TRAUMA	8/4	4/4	8/8
HI SUS	8/2	11/6	11/10

Pole +	**0-10**	**11-49**	**50+**
DOS	0/0	0/0	7/7
TRAUMA	8/4	2/2	10/10
HI SUS	8/2	9/4	13/12

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URGENCY Validation - Multiple Impacts

Pole +	0-10	11-49	50+
DOS	0/0	0/0	7/7
TRAUMA	8/4	2/2	10/10
HI SUS	8/2	9/4	13/12
Multiple	**0-10**	**11-49**	**50+**
DOS	0/0	0/0	7/7
TRAUMA	8/4	2/2	10/10
HI SUS	6/0	6/1	18/17

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Frail Individual missed

URGENCY Validation - Close-in

Multiple	0-10	11-49	50+
DOS	0/0	0/0	7/7
TRAUMA	8/4	2/2	10/10
HI SUS	6/0	6/1	18/17

Close-in	0-10	11-49	50+
DOS	0/0	0/0	7/7
TRAUMA	4/0	1/1	15/15
HI SUS	6/0	6/1	18/17

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Better Predictors - Frontals

- Pole Crashes at 20+ mph
- Multiple-impacts
- Close-in Occupants; Late deployments
- Other Factors
  - Frail Individuals
  - Complex Directions
  - Off-side Frontals

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Off-side Frontals

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Off-side Frontal (Driver)

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Off-side Case

- Case 98-006BL
- 2-o’clock
- 9 mph Delta-V
- Fatal

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9 mph Crash - Fatality

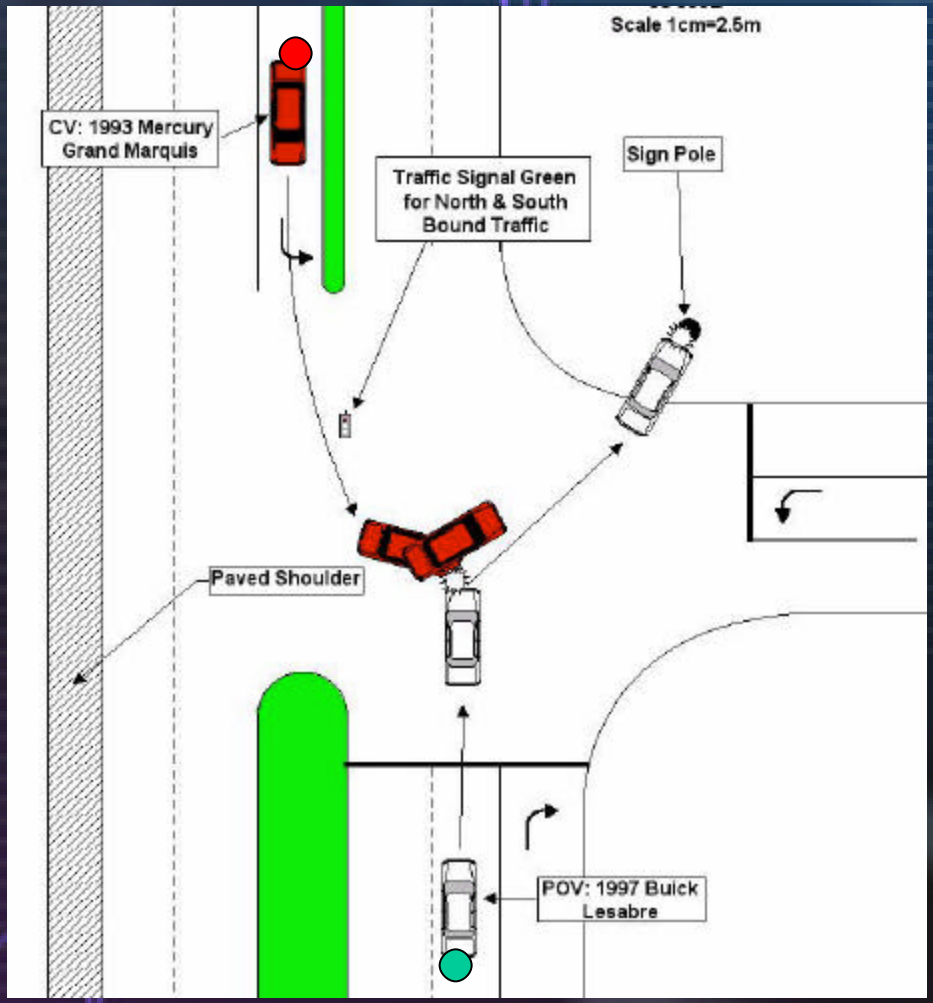
- 2 o'clock, 9 mph

- Restraints:

Lap & Shoulder Belt

Driver & Passenger

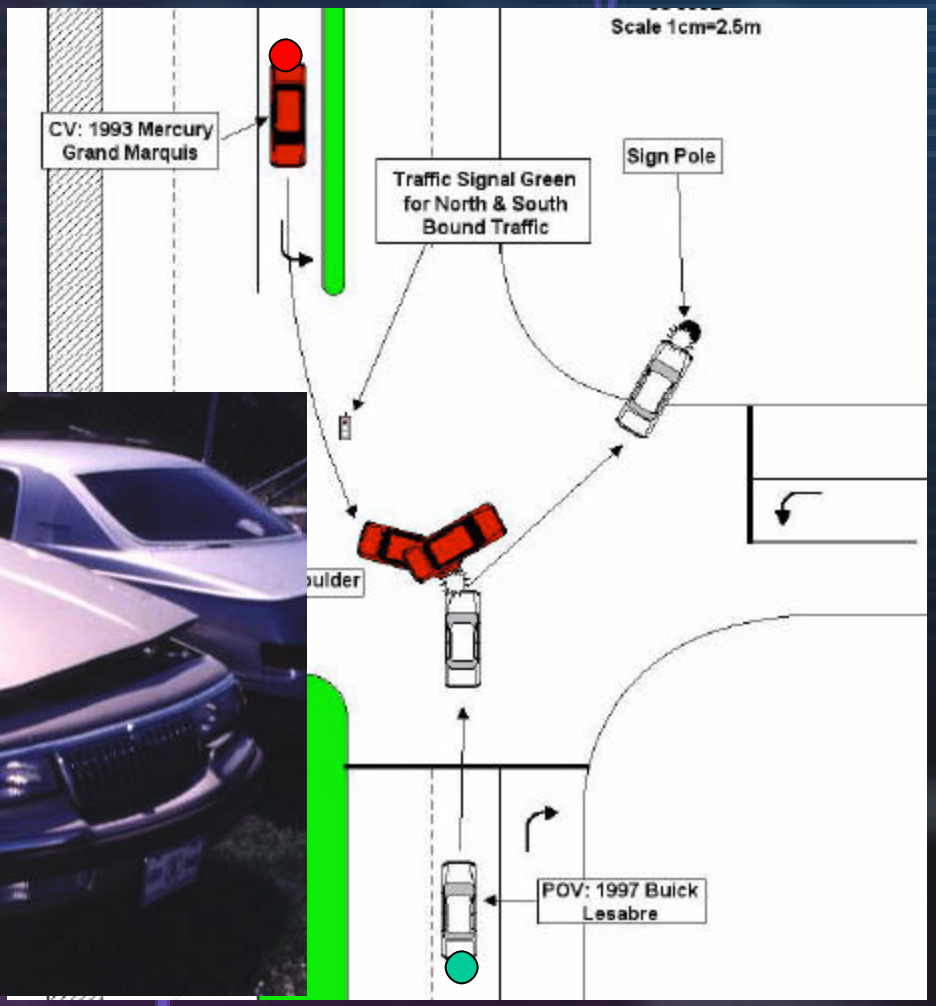
Air Bags Deployed



Case 98-006BL

9 mph Crash - Fatality

- 2 o'clock, 9 mph
- '93 Mercury Marquis



Case 98-006BL

9 mph Crash - Fatality

- Male Driver; 77 YO; 68” Tall; 272 Lbs
- Veh. - ‘93 Mercury Marquis
- POV- ‘97 Buick LeSabre
- 2 o’clock, 9 mph
- 10” Max Crush
- No Intrusion

Case 98-006BL

9 mph Crash - Fatality

Upper Body Markings

Case 98-006BL

9 mph Crash - Fatality

Case 98-006BL

9 mph Crash - Fatality

- Trauma Criteria - Expired at Scene
- Restraints-

Lap & Shoulder Belt

Air Bags Deployed

Case 98-006BL

9 mph Crash - Fatality

AIS-5 Brain Injury
Passenger Air Bag
Contact

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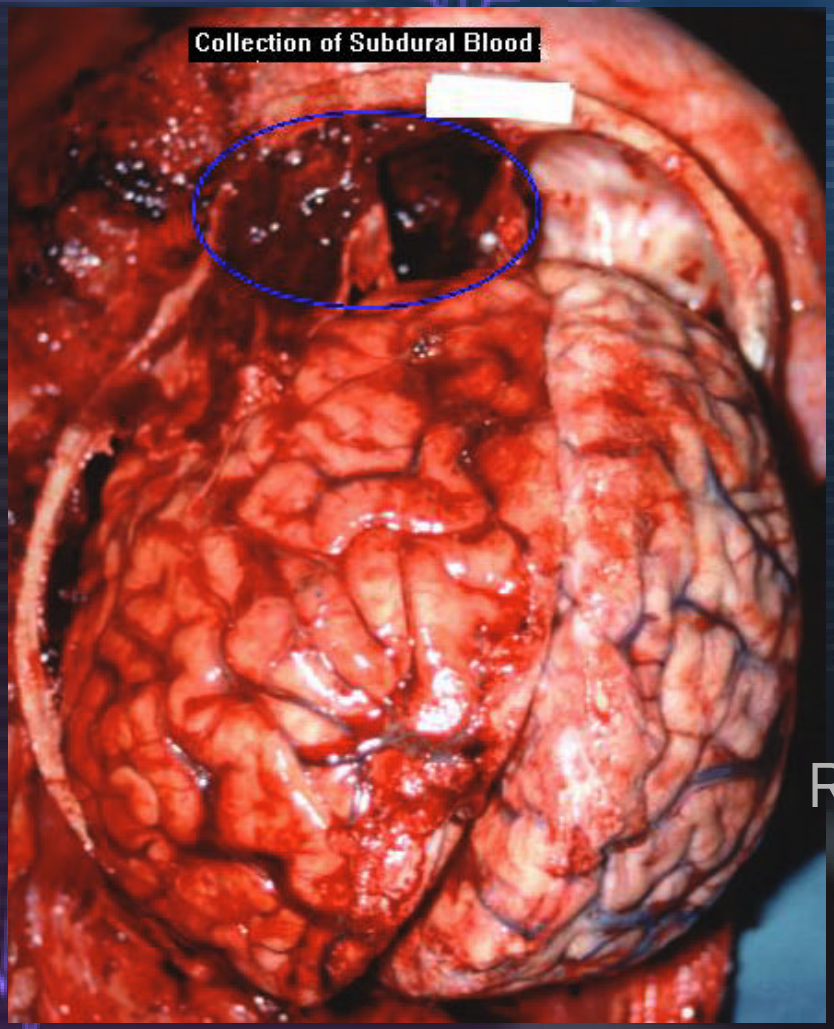
Case 98-006BL

9 mph Crash - Fatality

- **Belt Induced Injuries**:
  None
- **Other Injuries:**
  AIS 5 - Brain
  Passenger Air Bag



Left

Right

Case 98-006BL

Observations

- Shoulder Belt has Limited Effectiveness in Off-side Crashes
- Adjustments in URGENCY Algorithm May be Necessary

Past Studies Have Shown that
2-point Belts
Require Triage Criteria
Adjustment
in Far Side
Offset Frontal Crashes

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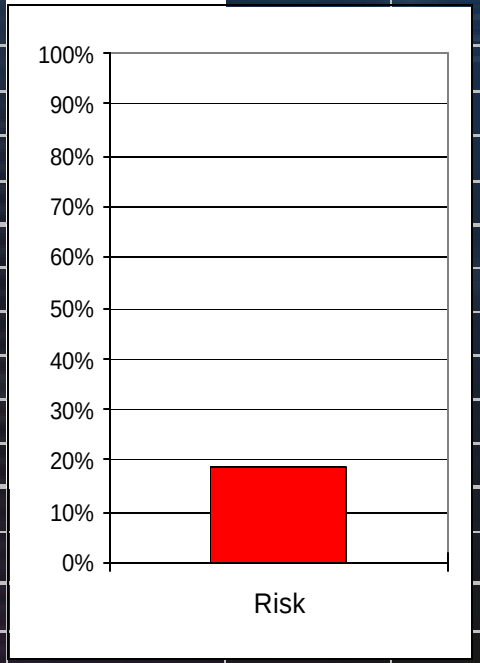
Injury Risk- 3-Point Belts

Vehicular Crash Site Data	Value	Data
Damage to Left Front? (Left Front=1)	1	L. Front
Damage to Center Front? (Center Front=1)	1	C Front
Damage to Right Front? (Right Front=1)	0	NO
Damage Greater Than 15"?(G.T. 15"=1)	1	G.T.15
Damage Greater Than 25"?(G.T. 25"=1)	1	G.T. 25
Damage Greater Than 35"?(G.T. 35"=1)	0	L.T. 35
Single Vehicle Crash? (Single Vehicle=1)	0	MULTI.
Rollover? (Rollover=1)	0	NO ROLL
Entrapped or Ejected? (NO=0, YES=1)	0	NO
Driver? (DRIVER=1, PASSENGER=0)	1	DRIVER
Occupant's Gender? (FEMALE=1, MALE=0)	0	MALE
Car Occupant's Age, in years? (Default 30 yr.)	30	TRUE
Safety Belt Use? (NO BELT=0, YES, BELT=1)	1	YES
Shoulder Belt Without Lap Belt? (NO LAP=1)	0	W LAP
Probability of Severe Injury	**19%**	

Serious Injury Risk



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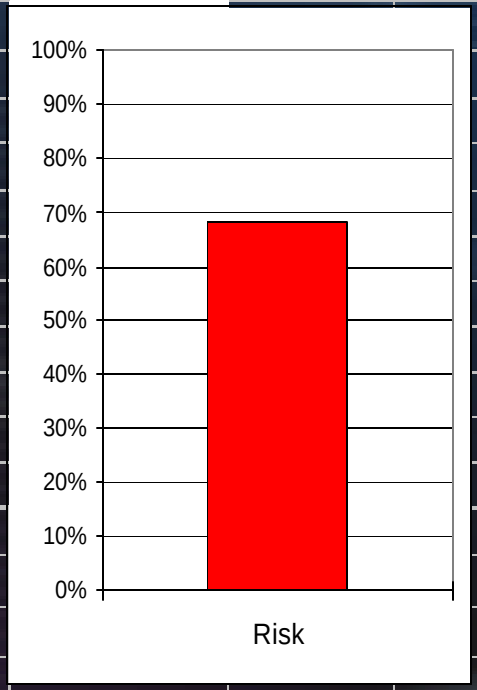
Injury Risk 2-Point Belts

Vehicular Crash Site Data	Value	Data
Damage to Left Front? (Left Front=1)	1	L. Front
Damage to Center Front? (Center Front=1)	1	C Front
Damage to Right Front? (Right Front=1)	0	NO
Damage Greater Than 15"?(G.T. 15"=1)	1	G.T.15
Damage Greater Than 25"?(G.T. 25"=1)	1	G.T. 25
Damage Greater Than 35"?(G.T. 35"=1)	0	L.T. 35
Single Vehicle Crash? (Single Vehicle=1)	0	MULTI.
Rollover? (Rollover=1)	0	NO ROLL
Entrapped or Ejected? (NO=0, YES=1)	0	NO
Driver? (DRIVER=1, PASSENGER=0)	1	DRIVER
Occupant's Gender? (FEMALE=1, MALE=0)	0	MALE
Car Occupant's Age, in years? (Default 30 yr.)	30	TRUE
Safety Belt Use? (NO BELT=0, YES, BELT=1)	0	NO
Shoulder Belt Without Lap Belt? (NO LAP=1)	1	NO LAP
Probability of Severe Injury	**68%**	
		SUSPECT LIVER INJURY



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Basis for Change in URGENCY

AAAM 2000 Paper by Augenstein, et. al.

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Population of Occupants

Restraint	NASS Belted (Exposed)	Lehman Belted (Injured)	Ratio
2- point	13%	32%	2.4
3-point	87%	68%	0.8

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WLRIC- 48 Cases of Drivers with 2-Point Belts

Liver Injuries - 50%

From the Population with Liver Injuries:

Occult Liver Injuries - 78%

Mal-triaged Liver Injuries - 25%

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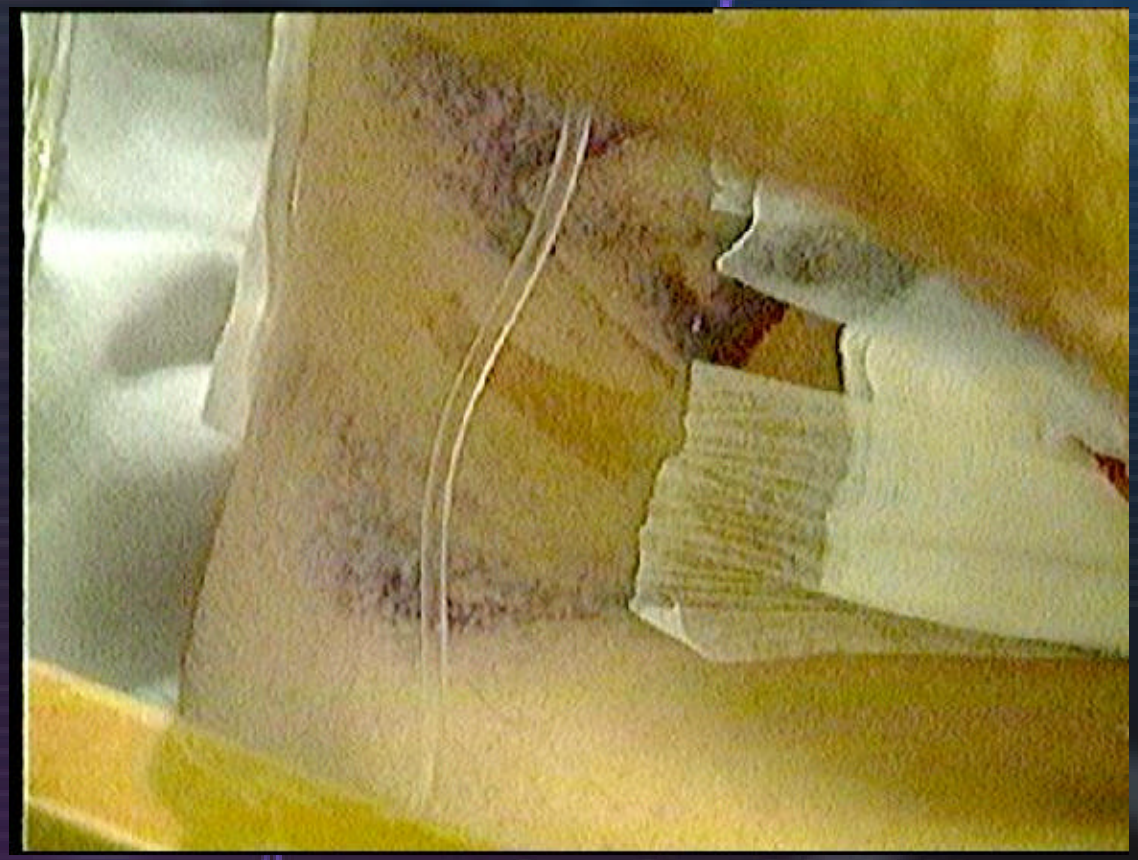
Case 94-003 Shoulder Belt Only Right Flank Bruises

dV=19 mph

PDOF- 1 O'clock

Liver Injury- AIS-4



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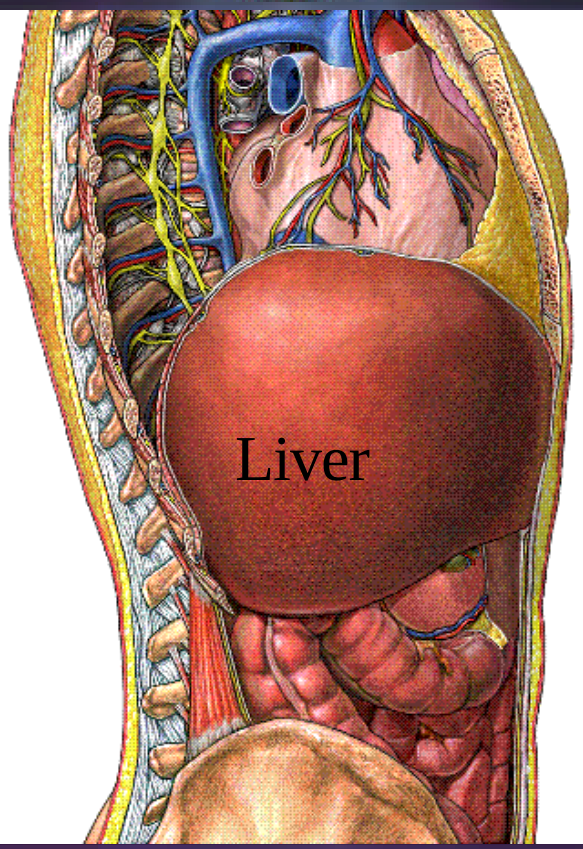
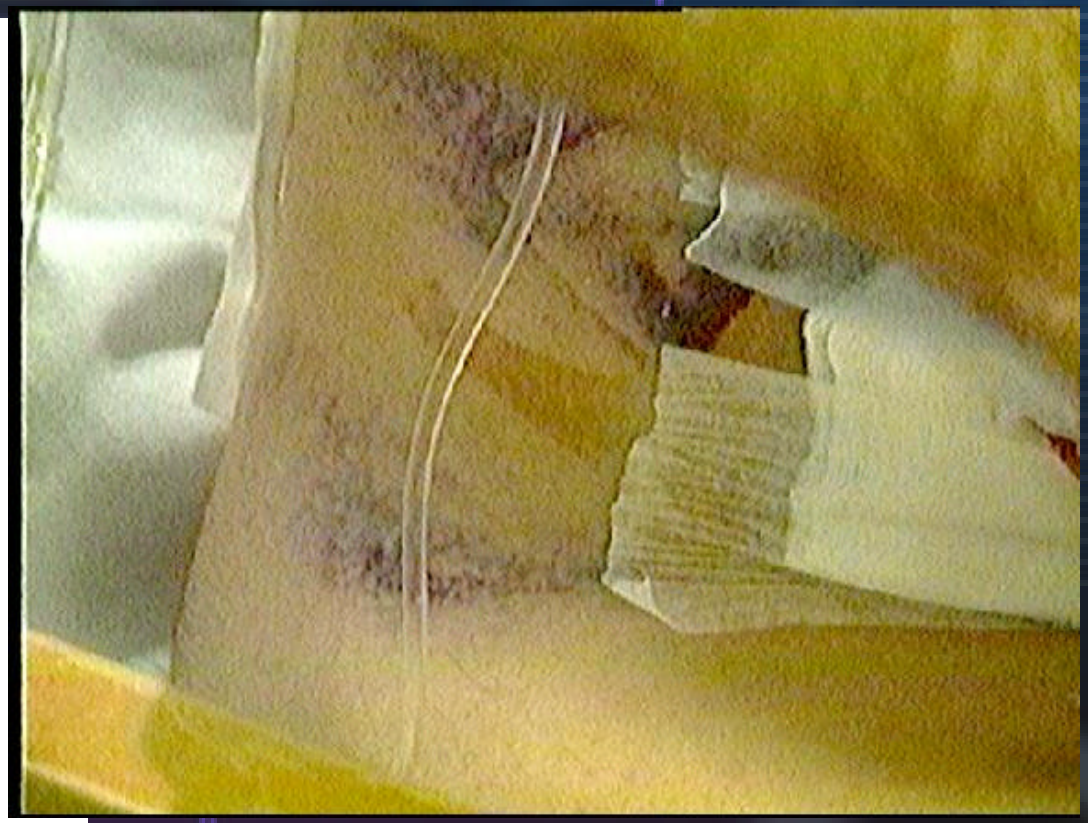
Location of Liver and of Belt Marks





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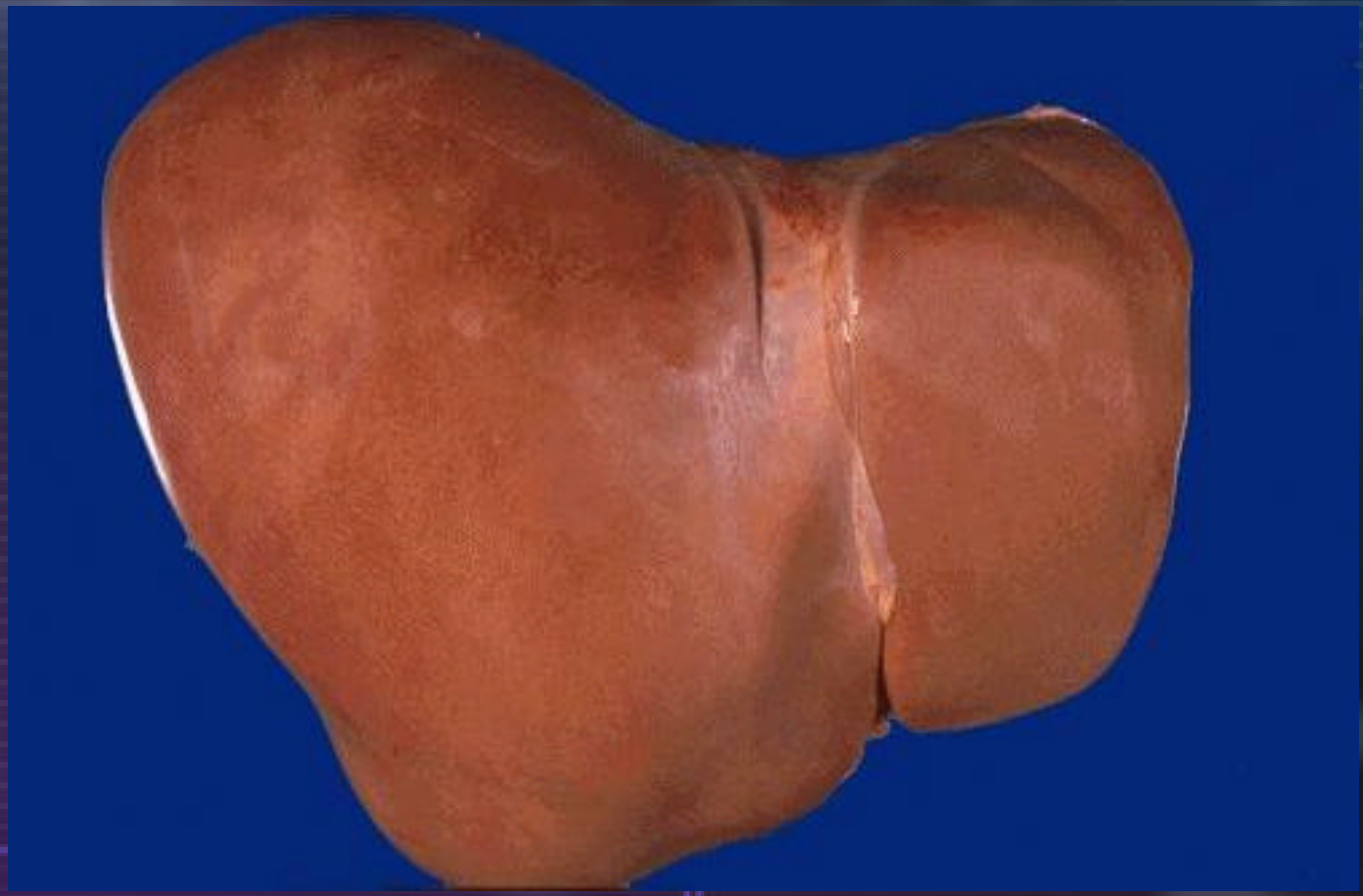
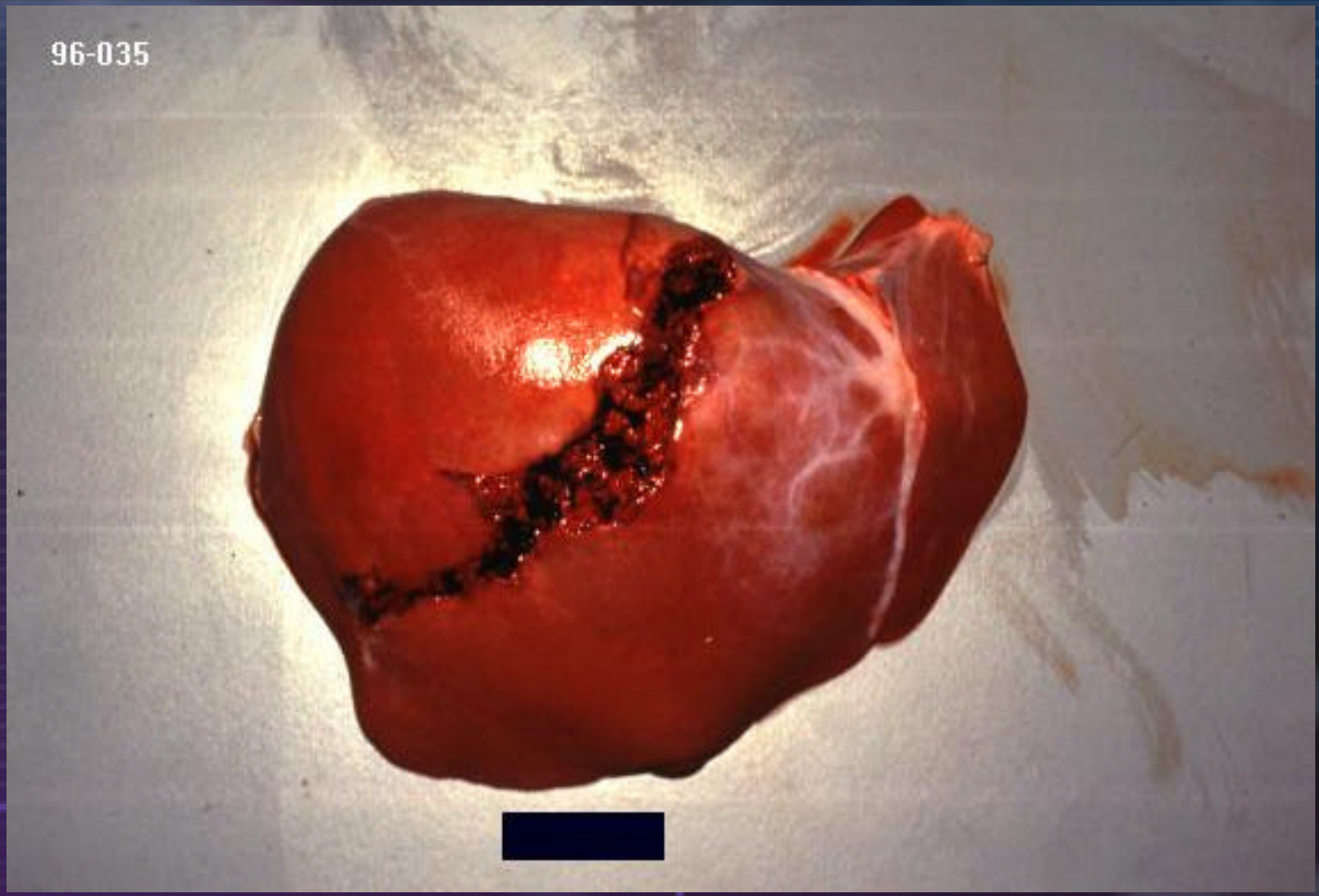
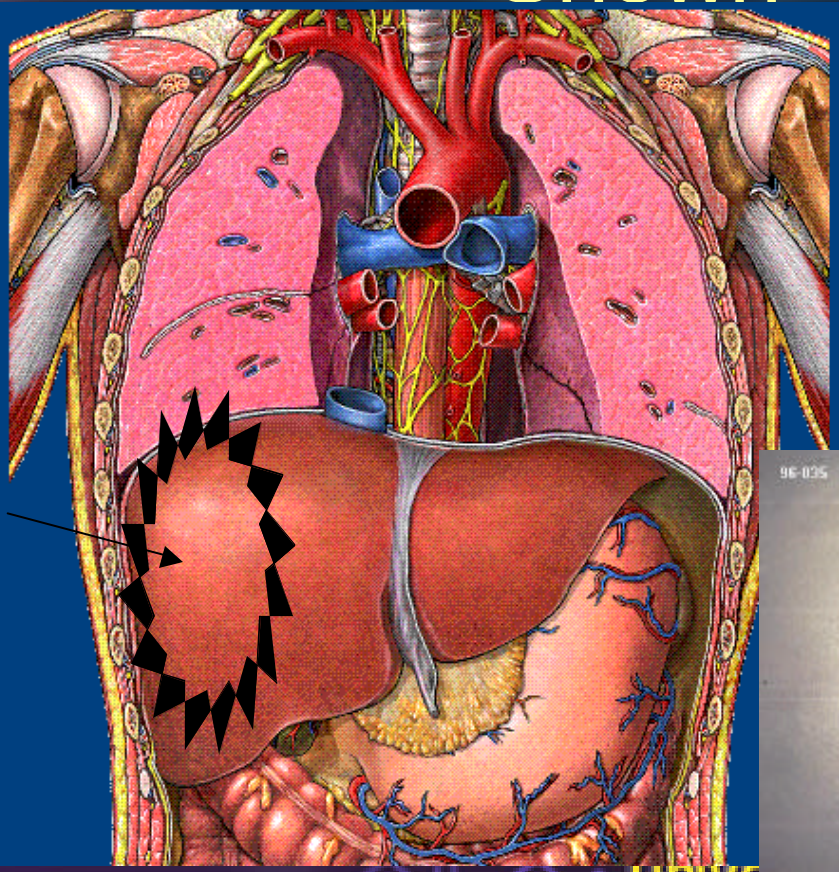
Undamaged Human Liver



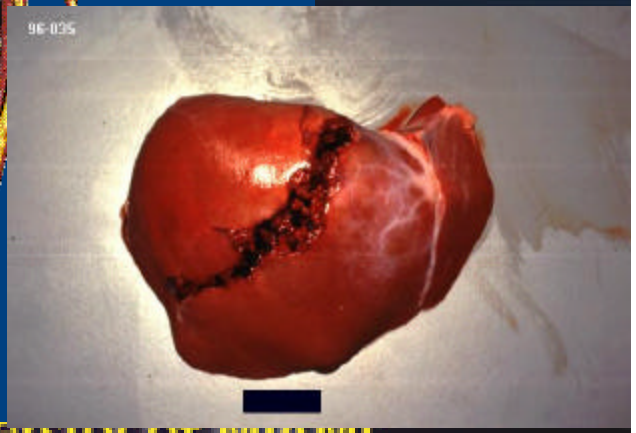
Liver Laceration Caused by Belt Loading



All Case to Follow Had Liver Injuries of Type Shown



Injury Location



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Belt Geometry Comparison

3-Pt Belt

2-Pt Belt

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Characteristics of Liver Injury Cases

- Driver in 2 - Point Belt
- Right Front Vehicle Damage (Low Delta-V)
- Liver Injury on Right Rear Lobe

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16 Cases to Follow

96-020 AIS-3 dV=12 mph

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97-049 AIS-5 dV=12 mph
Air Bag

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97-018 AIS-5 dV=15 mph

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96-041 AIS 3 dV=16 mph
Air Bag

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94-005 AIS-4 dV=16 mph

Air Bag

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93-013 AIS-4 dV=17 mph

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96-016 AIS-2 dV=18 mph

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94-003 AIS-4 dV=19 mph

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96-008 AIS-5 dV=19 mph

Fatal

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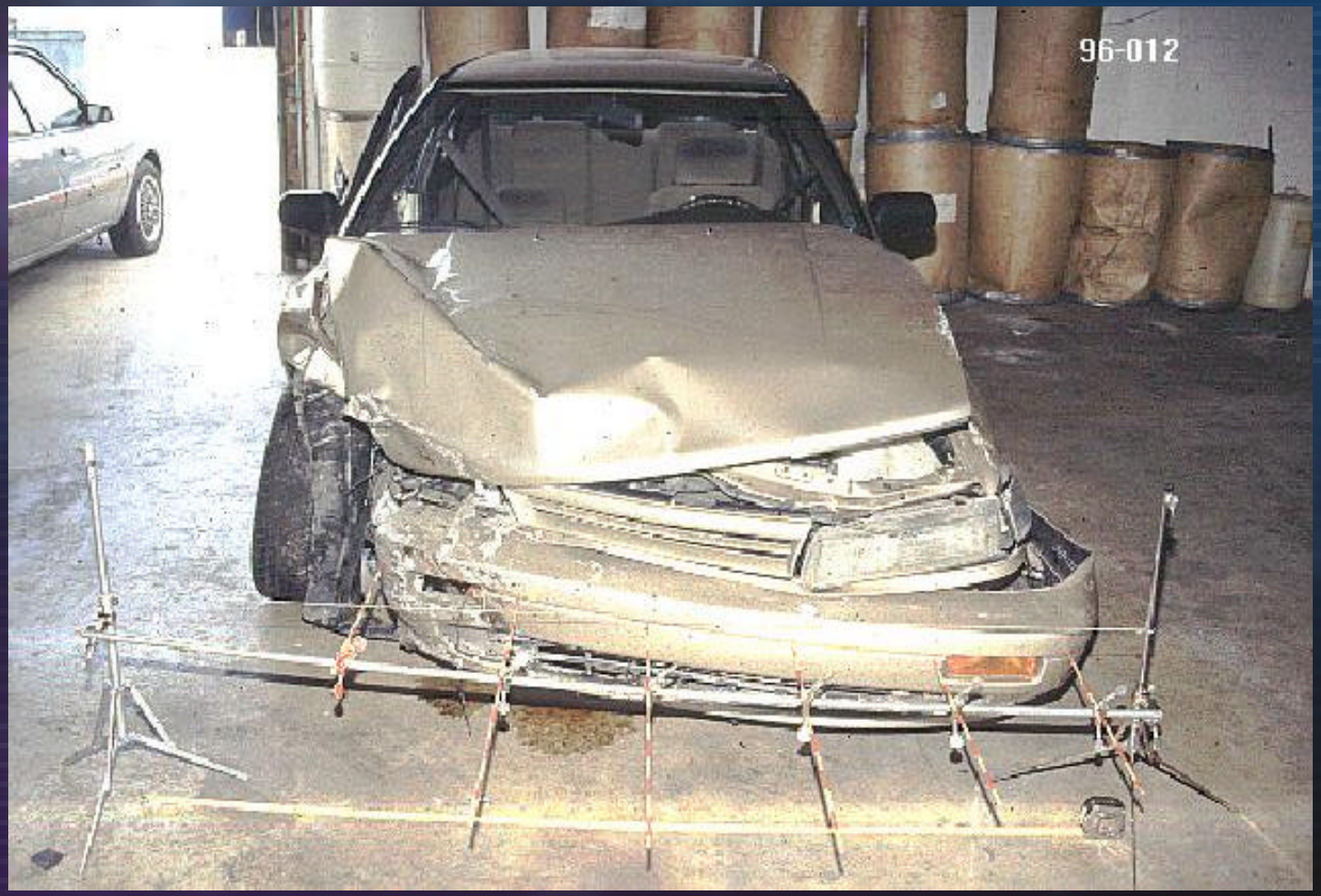

96-012 AIS -5 dV=19 mph
Fatal

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97-047 AIS-4 dV=19 mph

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92-029 AIS-2 dV=20 mph

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91-011 AIS-4 dV=25 mph

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96-035 AIS-4 dV=25 mph

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94-008 AIS-4 dV=26 mph

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93-017 AIS-3 dV=27 mph

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Are 3-point Belts Vulnerable to Injury in Off-side Crashes?

Case Studies from WLRIC

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Driver and 3-Point Restraint

1 O’clock PDOF

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Vehicle Damage

- Case Vehicle: 1988 Chevrolet Corsica
- PDOF: 1 O'clock
- DeltaV: 20.6 mph
- Max Crush: 12.5"
- Type: Frontal Offset
  Vehicle to Vehicle
- POV: 1989 International
  School Bus

Case #95-012

Occupant Information

- Case Subject: 70 Year Old Female
  - 64” 125 lbs.
- Position: Driver
- Restraint: Lap and Shoulder
  - No Air Bag
- Admitted
  - LOS: 11 Days

Case #95-012

Injuries

Belt Restraint

- Contusion, Heart AIS-3
- Contusion, Chest, Right AIS-1
- Abrasion, Neck, Anterior AIS-1

Toe Pan

- Fx Malleolus, Left Posterior AIS-3
- Fx Malleolus, Left Medial AIS-2
- Fx Fibula, Left AIS-2
- Fx Fibula, Right AIS-2
- Fx Malleolus, Right Medial AIS-2

Case #95-012

Complications

- Heart Contusion In 70 Year Old Female
- Multiple Lower Extremity Fractures
  - Compounds Rehabilitation For Elderly

Case #95-012

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Case Significance

- Restraint System To Stiff For Elderly
  - Results In Heart Contusion
- Good Outcome For Elderly Driver
  - Length Of Stay 11 Days
- Off-side Frontal Crash

Driver and 3-Point Restraint

1 O’clock PDOF

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Vehicle Damage

- Case Vehicle: 1990 Nissan Pathfinder
- PDOF: 1 O'clock
- DeltaV: 26 mph
- Max Crush: 23"
- Type: Frontal Offset
  Vehicle to Vehicle
- POV:
  1987 Toyota Camry

Case #98-017

Occupant Information

- Case Subject: 49 Year Old Female
  64” 170 lbs.
- Position: Driver
- Restraint: Lap and Shoulder
  No Air Bag
- Admitted
  LOS: 8 Days

Case #98-017

Injuries

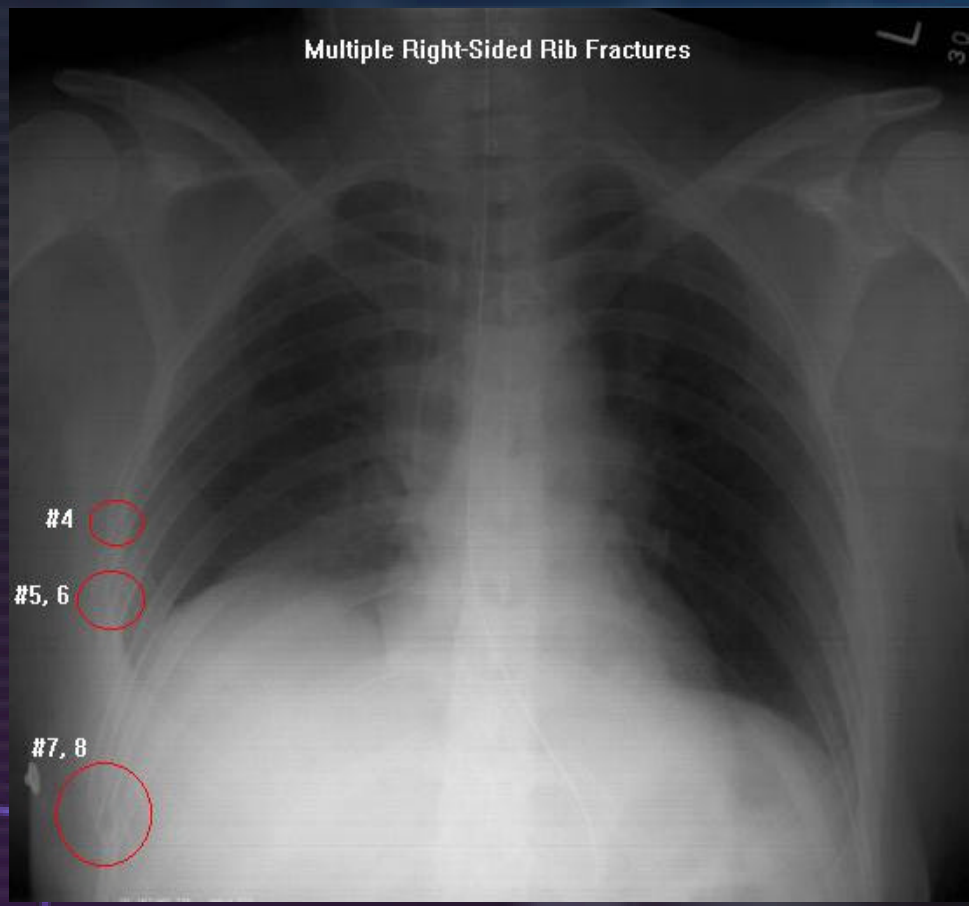
Belt Restraint

- Fx Ribs, Right AIS-3
- Avulsion, Omentum AIS-3
- Tear, Small Intestine AIS-2
- Abrasions, Multiple AIS-1
- Contusions, Multiple AIS-1

Steering Wheel Rim

- Contusions, Multiple AIS-1

Case #98-017



Complications

- Multiple Right Sided Rib Fractures
- Abdominal Injuries From Lap Belt Loading

Case #98-017

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Case Significance

- Incompatible Vehicle Impact
  - Case Vehicle Size Helped Driver In Severe Impact
- Restraint Geometry Unfavorable To Short, Obese Female
- Abdominal Injuries From Lap Belt Suggest It was Not Tight Over Iliac Crests
- Off-side Frontal Crash

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Driver and 3-Point Restraint

1 O’clock PDOF

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Vehicle Damage

- Case Vehicle: 1987 Buick Century
- PDOF: 1 O'clock
- DeltaV: 24 mph
- Max Crush: 11"
- Type: Frontal Offset
  Vehicle To Vehicle
- POV:
  - 1987 GMC Jimmy

Case #98-046

Occupant Information

- Case Subject: 68 Year Old Female
  59” 108 lbs.
- Position: Driver
- Restraint: Lap And Shoulder
  No Air Bag
- Died In Resuscitation

Case #98-046

Injuries

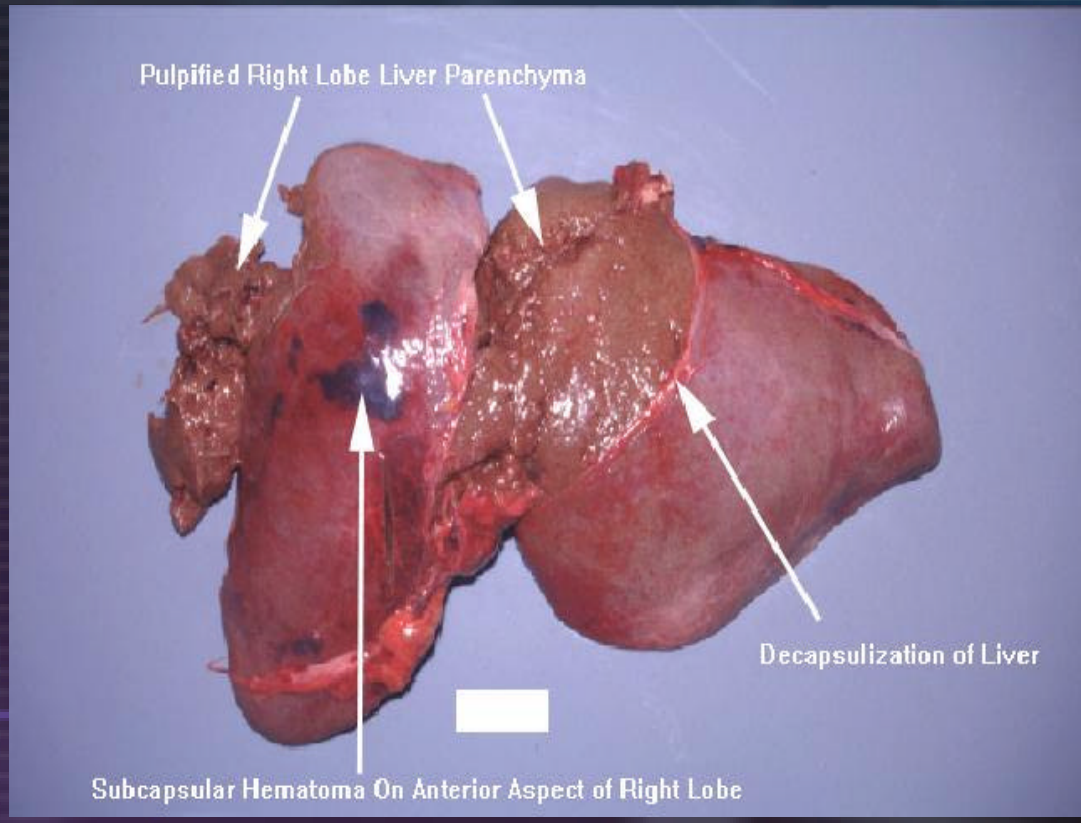
Belt Restraint

- Laceration, Liver AIS-5
- Laceration, Vena Cava AIS-4
- Fx Ribs, Right AIS-3
- Laceration, Lung Right AIS-3
- Compression Injury
  Lumbar Spine AIS-3
- Fx Lumbar Vertebra AIS-2

Steering Wheel Rim

- Fx Ribs, Left AIS-2
- Laceration, Lung AIS-3

Case #98-046



Complications

- Severe Chest Trauma In Elderly Female
- Severe Liver Laceration From Belt Loading
  Liver Pulpified In Multiple Lobes

Case #98-046

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Case Significance

- Restraint Geometry Unfavorable To Short Female
- Multiple Impact Crash Produced Increase Belt Load On Driver
- Moderate Impact With Fatal Results To Elderly Driver
- Off-side Frontal Crash

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RF Passenger and 3-Point Restraint

11 O’clock PDOF

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Vehicle Damage

- Case Vehicle: 1989 Oldsmobile 98
- PDOF: 11 O'clock
- DeltaV: 25 mph
- Max Crush: 33"
- Type: Frontal Offset

  Barrier Impact

Case #98-011

Occupant Information

- Case Subject: 70 Year Old Female
  62” 130 lbs.
- Position: Right Front Passenger
- Restraint: Lap And Shoulder
  No Air Bag
- Admitted
  LOS: 9 Days

Case #98-011

Injuries

Belt Restraint

- Fx Thyroid Cartilage AIS-2
- Fx Arytenoid Cartilage AIS-2
- Abrasions/Contusions, Multiple AIS-1

Toe Pan

- Fx Malleolus, Media,l Left AIS-2
- Fx Fibula, Distal, Left AIS-2

Case #98-011

Complications

- Multiple Left Lower Extremity Injuries
- Neck Injuries From Belt Loading

Case #98-011

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Case Significance

- Restraint Geometry Unfavorable To Short Female
  - Resulted In Neck Injury
- Barrier Impact Crash Produced Clockwise Rotation
  - Increased Belt Load On Right Front Passenger
- Moderate Speed Impact With Favorable Results For Passenger
  - Discharged In 9 Days
- Off-side Frontal Crash

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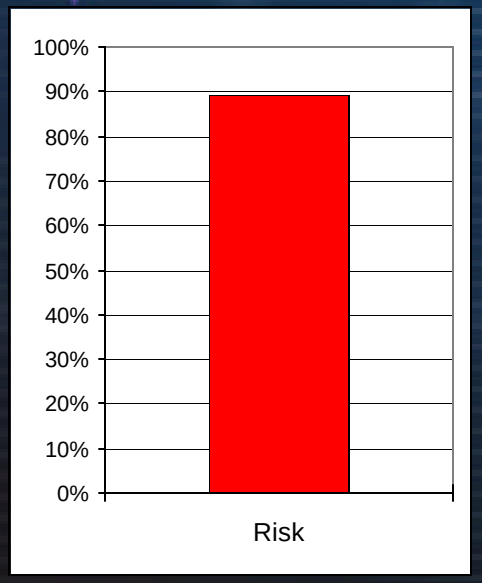
Conclusions

CIREN Data Needs to be Used to Improve Injury Prediction and Treatment

Crash Information Could Improve Triage and Outcome



Risk

89%

SUSPECT LIVER INJURY

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